Warm Forming of High-Strength Aluminum Automotive Structural Parts: A Success Story

Hyunok Kim, EWI Forming Center Director
EWI

Introduction

The automotive industry is challenged to produce vehicles with high customer appeal, improved crash performance, reduced fuel consumption, and reduced carbon dioxide (CO_2) emissions to meet market demands and increasingly stringent government regulations. One of the few enabling technologies to help the automotive industry meet these multiple challenges is lightweight structural components. The automotive industry is steadily adopting lighter and stronger sheet materials, such as ultra-high strength (UHS) steels and high-strength (HS) aluminum alloys, to achieve these goals.

Figure 1. JIP Final Project Review Meeting at EWI Forming Center on April 5th, 2018

Joint Industry Program on Warm Forming for HSA Structures

To support these goals, EWI and twelve industry partners launched a Joint Industry Project (JIP) team in October 2015. The project goal was to develop advanced and practical warm forming technology for high-strength aluminum (HSA) automotive structures. The project focused on an economical method of warm forming aluminum. This method involved adding a furnace and transfer equipment to existing cold stamping presses.

An industry-practical solution for bringing aluminum warm forming to market would require innovative solutions to eliminate the need for post-forming heat treatment and improvement of the formability limits to maintain cost competitiveness.

In early April 2018, EWI hosted a final project review meeting with 12 industry partner representatives and the representatives of the State of Ohio (Figure 1). The meeting also included two demonstrations of warm forming test with aluminum 7xxx alloy at the established warm forming test cell and cold stamping of aluminum 6xxx alloy at the 300-Ton servo press.

The JIP started by establishing warm and cold forming test cells at EWI and updating the state-of-art information on cold and warm forming of aluminum alloys. The established test cells were effectively used to create warm and cold forming solutions with the seven selected aluminum alloys and demonstrated the feasibility of the solutions with different test tools in a lab-scale environment. Several test tools were designed and fabricated to characterize the material properties/lubricant performance and demonstrate the feasibility of the cold and warm forming solutions. EWI also developed prediction capability and implemented it with multiple commercial finite element modeling (FEM) software.

Implementation of Practical Warm Forming Technology

Both cold and warm forming solutions were implemented using four example parts at an industry partner’s production facility to evaluate the manufacturing feasibility. In January 2018, the project team successfully implemented practical warm forming technology to produce high-strength and lightweight aluminum double doors (Figure 2) at American Tooling Center in Grass Lake, Michigan. Warm forming technology enabled the team to produce quality door inner parts with no defects such as wrinkling and necking compared to cold forming of the same aluminum 6xxx alloy. With the production-like batch run of this new process, the cycle time of furnace heating, automated part transferring and die stamping was found to be less than 90 seconds. There are more opportunities to further reduce the cycle time of the warm forming by improving the heating method and the automation programming. This would produce cycle times similar to cold stamping.

More importantly, this technology can be practically executed using a conventional furnace, part handling equipment and mechanical/hydraulic presses.

The project team conducted extensive work from the characterization of material properties and lubricant performance to tooling/process design using FEA and through prototyping of industry example parts. In addition to the door inner parts, EWI Forming Center and industry partners successfully implemented the warm forming process to produce the sidebar crash parts with ultra-high-strength (UHS) 7xxx aluminum alloy at American Tooling Center in 2017. These prototype parts can bolster both confidence and knowledge of the industry partners in the manufacturing of aluminum warm formed structural parts for lightweighting of the next generation vehicles.

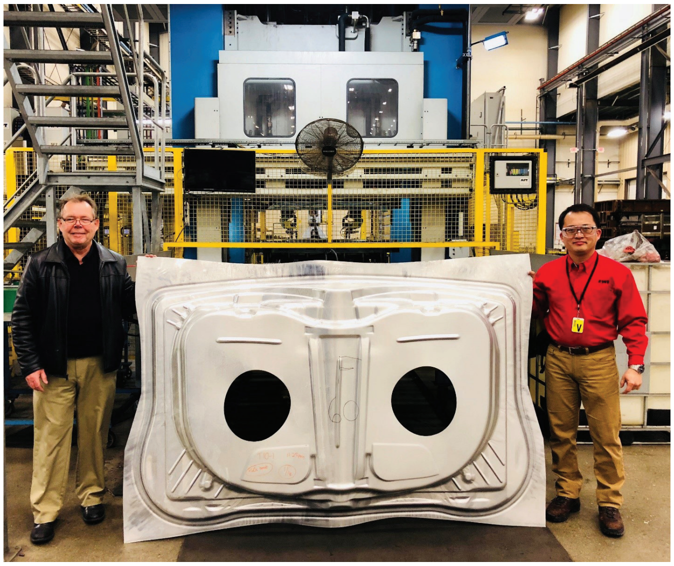

Figure 2. Warm-formed aluminum dual door inner part

Conclusion

The project team successfully completed the “proof-of-concept” of this unique technology with four different industry stamping designs. Through extensive testing and engineering evaluations for the forming solutions, a design guideline was established for a cost-effective warm forming solution for aluminum alloys. EWI believes this design guideline can help industry partners implement the developed manufacturing solutions in cold and warm forming of various aluminum alloys (5xxx,6xxx,7xxx). EWI plans to use the developed design guidelines to train industry professionals to comply with the State of Ohio’s governmental support requirements for this project.

The following are major conclusions from this project:

- Servo-press technology showed quality improvement when drawing parts. An FEM-based optimization tool can be used to determine the preferred servo-press slide motion and cushion force profile to avoid necking failure when drawing aluminum parts.
- Warm forming process windows determined by EWI for aluminum 6xxx and 7xxx alloys were successfully implemented to produce the industrial example parts, such as the door and sidebar components.
- Current aluminum production equipment is capable of warm forming aluminum (tandem and transfer, and possibly progressive).
- Overall costs of warm-formed aluminum stamping should be similar to cold aluminum stamping, with comparable speeds and only slightly higher tooling costs.
- Commercial FEM software such as AutoForm, DynaForm, and Pam-Stamp are good predictors of thinning, forming limit diagram, and springback after implementing the material input data produced from the project.
- Both optimal warm forming temperature and robust lubrication are equally important for warm forming practices.
- An approximately 12% strength drop was experienced with aluminum 6xxx and 7xxx alloys from warm forming, and paint-bake processes. This should be considered for product designs.

To learn more, contact the EWI Forming Center’s Director, Hyunok Kim (hkim@ewi.org or 614.688.5239), or visit https://ewi.org/ewi-forming-center/.

***Hyunok Kim**, Senior Engineer and Director of the EWI Forming Center, has a diverse background of academic, industry, engineering, research, and teaching experience. His areas of expertise include cold/warm/hot sheet and bulk forming technologies, forming equipment, tribology, simulations, and formability testing/analysis. He has led numerous government- and industry-sponsored research programs of hot and warm forming of automotive and aerospace structures, manufacturing fuel cell components, and shear fracture/edge cracking in stamping advanced high strength steel(AHSS), springback control, and crash modeling of AHSS automotive structure parts.*